THE POTENTIAL OF THE NAVSTAR GLOBAL POSITIONING SYSTEM FOR THE CORPS OF ENGINEERS, CIVIL WORKS

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INTRODUCTION

The Department of Defense is in the process of deploying a new satellite system for the purpose of navigation and point positioning. While designed primarily for military applications, the system has great potential for civilian use as well. In particular, the use of the Global Positioning System (GPS) in a geodetic mode may yield rapid, accurate geodetic positions in three dimensions. Thus, in the near future, GPS -.11 become a valuable new tool to the Corps surveyor.

HISTORY

Man has always used the stars to navigate or find directions and more recently to fix his position on the surface of the earth. When the first artificial satellites were put into orbit they were used almost immediately for geodetic positioning. From its beginnings in the late 50s with the use of satellite tracking cameras, the technique has evolved into the modern systems of today with microwave transmitters on board the satellites.

The Army SEquential Collation Of Range (SECOR) and the Navy TRANSIT are examples of such electronic systems. The SECOR system was intended for precise geodetic positioning through range measurements and was only partially successful. The TRANSIT navigation satellites are still in use today for both navigation and point positioning.

THE TRANSIT DOPPLER SYSTEM

Because the TRANSIT navigation system is one which has been remarkably successful and has been adapted to the civilian sector, and because NAVSTAR will replace this system, it would be of interest to understand TRANSIT's evolution and history.

TRANSIT was developed for military use starting in 1958. It was designed to be a marine navigation aid and that remains its primary role today. However, in the late 60s equipment was developed to use TRANSIT for land surveying. The most important application is point positioning. In contrast to satellite position fixes taken on a moving vessel in which each position fix is used independently to update the dead-reckoned position, fixed point

Errata Sheet

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differs from
Robertson, Ken. Same title.
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on these points:

p. 391 ¶ 3 Reordering of the acronym & definition

Long ¶ 4 broken into ¶ 4 & ¶ 5

392 Item 3 added; others renumbered

393 ¶ from Robertson Feb 85 omitted

¶ 5 Sentence added

¶ 6 Sentence added

394 ¶ 4 Cost sentence deleted

¶ 6 Added

¶ re Cost revised

395 Conclusion ¶ revised

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positioning requires data from mulciple satellite passes at a single location. With appropriate data processing techniques, good survey results may be obtained, thus avoiding the land traverse required by conventional survey methods. A horizontal positioning repeatability of less than 5 meters can be expected after 25 satellite passes.

A second way of using the TRANSIT satellite is in a relative or translocation mode. In this mode, data from two or more receivers are combined in such a way that the relative position between the receivers may be found to less than one meter. When one receiver is placed on a known point, the coordinates of the other point may then be accurately determined.

The Federal Geodetic Control Committee has tested the TRANSIT system in the translocation mode. They say:

> "Analysis of the test results indicated that with about sixteen passes (generally one day of observations) it is possible to compute the position of an unknown point relative to a known point to an accuracy of plus or minus 40 cm for latitude and longitude and about plus or minus 1 meter for the elevation (1 sigma estimates)."

USES OF THE TRANSIT DOPPLER SYSTEM

The TRANSIT system was originally designed for navigation of ships and it is to fulfill this function that the system is mainly used. But surveying is also an important use, and the one which we are concerned with here. Following is a list of some of the present uses of TRANSIT for surveying. These are, of course, uses to which the Global Positioning System would also be put.

1. Seismic Line Control. TRANSIT may be used to provide control for the end points of a seismic line and for quality control for the interior part of the line, which is done using conventional control surveying techniques.

2. Gravity Surveys. TRANSIT provides endpoint control for gravity surveys performed with an inertial surveying system.

3. Arctic Ice Movement. The TRANSIT system may be left unattended on the ice to accumulate a history of regional ice movements.

4. Control for Offshore Positioning. TRANSIT may be used to determine the exact position of offshore drilling platforms and ships.

5. Mapping Control. Resource mapping using aerial photography requires adequate ground control. This may be provided by TRANSIT in areas where conventional control is difficult to obtain.

6. Utility Line Control. Particularly in remote areas, a utility line route is selected from aerial photographs. The laying out of this

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route on the ground is made easier by using doppler satellite methods.

THE NAVSTAR GLOBAL POSITIONING SYSTEM

The NAVSTAR Global Positioning System (GPS) was originally conceived as a tool for military sea, land, and air navigation. The system consists of three parts: the satellites, the ground control network, and the user equipment.

Present plans call for the system to be implemented by 1988 using 18 NAVSTAR satellites, with three in each of six orbital planes. The orbits are approximately 20,000 kilometers above the earth, giving an orbit period of 12 hours. With this configuration, a user should be able to receive signals from at least four NAVSTAR satellites simultaneously at almost any point on earth (except the extreme polar regions), at any time.

Information from the satellites is transmitted by means of a pseudorandom code which is controlled by a cesium clock within the satellite. The user equipment measures the time of arrival of the pseudorandom pulses by adjusting its internal code generator to phase match the code being received from the satellite. Then, by knowing the time of arrival of signals from four satellites, it is possible to solve for position in three dimensions plus an accurate value for time. A lesser quality clock is required for use in the receivers.

GPS may be used in several modes, although all may not be available in the future to the civil surveyor. Direct access to the pseudorandom code in a high accuracy navigation mode (approximately 10 meters) will probably be denied to all but a few civil users, although a lower accuracy mode (200 meters) should be available.

The technique of most interest to Civil Works users is the differential, interferometric mode. In this mode, two or more GPS receivers simultaneously receive signals from the same set of satellites. The resulting observations are subsequently processed to obtain the interstation difference in position. If one of the receivers is placed at a known position, the three dimensional position of the second receiver may be determined. The number of stations determined simultaneously is limited only by the number of receivers available. Knowledge of the pseudorandom code is not required.

Accuracy projections for interstation position determinations using the GPS differential technique range between a few millimeters for baselines of a few kilometers, to a few decimeters for baselines of up to perhaps 5000 kilometers. These accuracies assume observations of from one to two hours in length. One ground station receiver system which is already in use claims to have demonstrated an agreement with National Geodetic Survey measurements of 1.3 parts per million in distance and 0.8 arc seconds in azimuth, over a line 36 kilometers in length.

POTENTIAL USES OF GPS FOR CIVIL WORKS

1. Quality Control. As the Corps of Engineers continues to contract for a greater proportion of their surveying and mapping product needs, while at the same time decreasing the number of in-house survey personnel quality control will become of increasing concern. A GPS antenna may be placed over a mark in the middle of a traverse and used to check a contractor's conventional survey for accuracy. If two intervisible points are checked, an azimuth may also be determined.

2. Elevations Along the Mississippi River. There is evidence that the whole of the Mississippi river basin is sinking, so that elevation benchmarks along the river are suspect. Since measurements of levee profiles are dependent on these benchmarks, they too may be in doubt. GPS could provide an elevation reference which is not subject to these errors. GPS could also be used to measure subsidence of marks along the river with reference to marks 100 kilometers away. In combination with an inertial survey system, measurements of levees would be better able to find low spots. It should be understood that GPS measures elevations to a different reference plane than a conventional leveling survey, and thus is not suitable for establishing absolute elevations. However it will measure changes in elevation with full precision.

3. Elevation Reference for Tidal Gauges. In the same way that GPS could be used to control elevation benchmarks along the Mississippi River, it could also be used to check tidal gauge elevations along coastlines.

4. Control in Remote Areas. GPS could be conveniently used to bring first or second order control into remote areas without the usual ground traverse or triangulation net.

5. Continuous Monitoring of Dams. There is also an interesting potential for continuous monitoring of dams and other large structures using GPS. In this case several antennas would be permanently mounted on the structure with another, reference antenna, mounted on stable ground a few kilometers away. Relative, two-dimensional movements could be detected at a level of less than five millimeters.

6. Navigation of Hydrographic Survey Vessels. In the differential mode it may be possible to determine the position of a survey vessel to $\pm$ 1 meter in real time.

COST

The approximate cost of a basic NAVSTAR GPS system is about $300,000, but will probably drop to the $125,000 range by 1986. Cost of a single receiver alone should be about $50,000, and this will be the most probable purchase for the private surveyor. He would operate the single receiver at various sites as a remote station while a service company in his area processes his collected data and provides him with the results. This might be the desired entry level for a Corps District as well.

THE FUTURE

It is becoming increasingly accepted that any future land records and information system will be based on a nationwide geodetic framework. This would not only provide an accurate and efficient means for referencing data, but also a uniform and effective means for distributing land records. In this regard, GPS represents a potential major breakthrough in providing efficient control densification. At the same time it poses the question as to whether densification is necessary.

The probable future configuration for use of the NAVSTAR GPS system by the private surveyor will be a single base station (which may be operated by a service company) at a convenient point within a limited geographic area, and any number of mobile stations operated by private surveyors (who may either own or lease the units). Survey reference would always be to the geodetic control network without the necessity of bringing control to the site in the conventional sense.

CONCLUSION

In view of the great potential of GPS, the Engineer Topographic Laboratories is in the process of purchasing a set of GPS receivers and a processing station. These will be used to evaluate the potential of this new technology for special purpose surveys such as monitoring the subsidence along levees on the Mississippi River or small movements of large structures. Additionally, surveys will be performed for various Corps Districts to introduce the technology to the field. The Global Positioning System holds great promise as the survey system of the future.